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Study of Radiation attenuation properties of shields consisting of Nano WO_3 epoxy for prevention from the gamma ray

Faris S. Atallah¹, Kareem K. Mohammad², Kamal M. Ali¹

¹ Department of physics , College of Science , University of Tikrit , Tikrit , Iraq

² Department physics , College of Science , Al- Nahrain , Baghdad , Iraq

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Name: Kamal M. Ali

E-mail: ka2215753@gmail.com

Tel:

ABSTRACT

In this study, the shielding properties of gamma rays for shields consisting of epoxy polymer were studied as a base material, reinforced by the oxide of Nano-tungsten oxide (WO_3), with different reinforced ratios (10,20,30,40%), different thickness, to determine the suitability of these shields for use in gamma ray protection. Some parameters were measured such as linear attenuation coefficient (μ), Half value layer, Using source (Cs-137) Emitter of gamma ray energy (662 Kev), Source (Co-60) The emitter of gamma ray energies (1172,1332 Kev). For this purpose, was used The sodium iodide detector NaI(TL) in the size of (1.5" \times 1.5")inches. The rate of radiation dose was also calculated using attenuation coefficients. The results showed that the linear attenuation coefficient increases when the supported ratio and the thickness of the shield increases and decreases when the gamma ray energy is increased for the radiation source used. The results showed that the dose-rate decreases with the increase in the ratio of the supported and the thickness of the shields, and increase with increasing the energy and radioactive activity of the source. As for the Half value layer decreases when increasing the percentage of support, the opposite happens when energy is increased.

Introduction

Radiation shielding is essential for the protection of human and environment because the harmful effects of ionizing radiations can cause significant health hazards with the development of technology, human health has started to be exposed to extra radiation and this can damage the human cell. There is always a need to develop material, which can be used under harsh conditions of nuclear ray's exposure and can act as shielding material [1]. Therefore, the shielding required realization on different types materials, mixtures, compounds to provision maximum preservation from radiation. Various materials have been used for this purpose such as concrete, lead and iron plates, but these materials are no longer suitable in many modern applications because of their cost and difficulty in using them. Therefore, attention was drawn to the use of composite materials to attenuate gamma rays to obtain new properties. Due to tremendous applications for nanomaterials, nowadays, use of the Nano-particles in materials has

enchantment for researches due to different features. The properties of nanoparticles can be engineered by managing their dimensions [2].

The aim of this research is to find new alternatives of nuclear shields easy to make and modulation made from epoxy composite supported with Nano-tungsten oxide (WO_3) powdered, He has a good ability to radiation attenuation of gamma-rays, with wide extent of application in the industrial, medical fields.

Theoretical concepts

Gamma rays is a name called electromagnetic radiation whose origin is from the nucleus [3]. When a γ -ray passes through a medium, the energy transfers to the medium as a result of the interaction that occurs between the photons and matter. This interaction can be resulting in a large energy transfer or even complete absorption of the photon. However, the photon can be scattered rather than absorbed and retain most of the initial energy while the change occurs only in the direction. There are three major

types of interactions causing attenuation of a photon beam by matter: photoelectric effect, Compton effect, pair production [4].

The Pierre-Lambert equation used calculates the linear attenuation coefficient, thus a beam of gamma rays is of primary intensity of I_0 of initial photons will have Remaining intensity of I after Crossing the material. According to the following relationship Eq. 1.

$$I = I_0 e^{-\mu x} \dots \dots (1)$$

Where μ is linear attenuation coefficient of the material (cm^{-1}) and (x) is thickness of the material.

The equation can be used on conditions when the photon beam is very narrow and parallel to the single energy and the thickness of the absorbent is very low. [5].

Half value layer was also calculated, which defined as the thickness needed to attenuate the radiation beam to half of what it was before entering the absorbent material [6]. Calculated using Eq.2.

$$HVL = \frac{0.693}{\mu} \dots \dots (2)$$

Where HVL value is in (cm).

The dose rate was calculated using Eq. 3, whereas dose rate (D), at the post-shield point is associated with the unprotected dose, (D_0), or the dose rate, without the shield [7].

$$D = D_0 e^{-\mu x} \dots \dots (3)$$

We used a personal dosimetry to measure the dose rate for gamma rays (D_0) when there was no protective shield.

The rate of radiation dose is calculated in units ($\mu Sv / h$) using the following relationship [8]: -

$$D = 0.142 \times A / d^2 \sum_i f \times E \dots \dots (4)$$

Whereas:

(A): radiation activity in unity MBq. (E): energy in unity Mev. (d): distance in unity m.

(f): This is the ratio of the number of photons of gamma released by the specified energy of the line to (100) dissolution of the radioisotopes.

When calculating the total radiation dose rate of the radioactive source containing more than one energy we use the following relationship:

$$D_t = \sum_i D \dots \dots (5)$$

Materials and methods

The materials used in this study for the preparation of composite samples as a gamma ray absorbent with different concentration and thickness are; epoxy resins ($C_{18}H_{24}O_3$) by negotiable a hardening by adding hardener, a commercial product (Epoxy UAE production). The reason for the choice of epoxy because it can be manufactured in dimensions and form required, and is characterized by high resistance against gamma ray.

The samples were made by the researcher, a component of the Nano- WO_3 powder as a compound supplement. This powder was selected due to high atomic number, high density and crystalline structure which increases the performance of radiation protection of the material [9].

The number of samples used in this study is 17 samples. (10%, 20%, 30%, 40%), different thickness (1,2,3,4 cm), pure epoxy with no additives of (1) cm thickness.

In order to measure the linear attenuation coefficient of the processed samples, was used a sodium iodide detector NaI (TL), Size (1.5 x 1.5) inches produced by radiation sensor LLC HARVEST, AL 35749 USA. Model 6S6P 1.5VDC2.

It has also been used (URAD-PLUS), manufactured by (CANBERRA) USA. To measure the dose rate (D_0) of radioactive sources without shields. And that The radioactive sources used in this work are Cobalt-60 (Co-60) radiation activity (1 mCi) and half-life (5.27y), which emit gamma photons with the values of energies (1172 KeV) and (1332 keV). And Cesium-137, (Cs-137) with radiation activity (9.49 μCi) and half-life (30.17 y), which produce gamma photons for energy value (662 KeV).

To get a narrow beam of photons gamma rays in order to examining the linear attenuation coefficient in the material shield has been arranged measurement system by using two collimators made of lead material and dimensions (4 x 16 x 16) cm where he put a collimator radioactive source, that contains a central circular aperture with diameter of (1 cm). and The distance between the detector and the radioactive source is 30 cm, as in the Fig.1 that represents the good geometric arrangement. The same geometric arrangement was used to calculate the dose rate (D_0) of gamma ray at a distance of (17 cm) for source (Cs-137) due to the limited activity of the source and at a distance of (30 cm) to source (Co-60) due to its high activity.

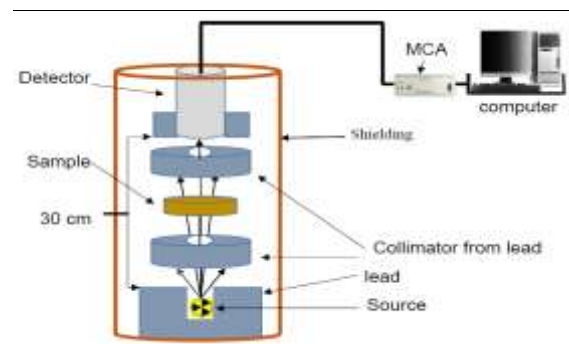


Fig.1 Good engineering arrangement of the metering system.

Results and Discussion

linear attenuation coefficients (μ) and half value layers (HVL) For all composites prepared were measured and Summarize the results in Table 1 for 662,1173.2 and 1332 Kev gamma ray energies. The Dose-Rate of gamma rays was also calculated. For both of the radiated source Cs-137, Co-60. and results are summarized in Table 2.

The linear attenuation coefficient and the half-thickness were calculated using a detector NaI(TL) through Eq. 1, 2, respectively as it is mentioned

before in theoretical Section, the results are summarized in Table 1 for both 662, 173.2 and 1332 Kev gamma energies.

In Fig.2, the linear attenuation coefficient displayed as a function of concentration of powder (WO_3) at the different energies. From fig.2 Note that the linear attenuation coefficient increased with the increase of concentration, especially at photon energy (662Kev), but at higher energies (1172, 1332Kev) Note that there is a slight change in linear attenuation coefficient values. Note that the measured linear attenuation coefficient of epoxy has a minimum value while reaching the maximum value in the samples supported by 40% of powder (WO_3) and from Table (1), we can increase the linear attenuation coefficient with the thickness of the samples and the different concentrations are clear and good. The improved shielding ability of metal powder/Ep composites could be interpreting on the fact that, Epoxy is a bad shielding substance, but when filling (WO_3) add mechanism, it was adjust and become a good shielding substance. In other word, there has been an increase in the probability of interaction between

gamma rays and shield atoms. thus, conclude that, the linear attenuation coefficient was increased with the increase of the reinforcement ratio of the prepared compounds, this is consistent with studies [10].

We note that linear attenuation coefficients increase when the concentration of Nano- WO_3 is increased in epoxy. Thus the WO_3 padding increased the radiation mitigation performance in the polymer matrix.

There is another way to determine the attenuation performance of compounds by comparing values (HVL) of the composites, Fig. 3.

According to the results, Fig.3 shows that the half value layers decreases with increasing concentration. This is due to the fact that the increase in the concentration of the additive improves the properties of the base material towards the gamma attenuation. Fig.3 shows that of the half value layers increases by increasing the energy. This can be explained by the fact that in the case of low energies, gamma rays need a half value layers less than in the case of high energies, which require a half value layers to attenuate to half their original value, this is consistent with studies [11].

Table (1): Linear attenuation coefficients (μ), values HVL at different energies for shielding Supported with(WO_3) powder at different Concentration percentages.

Comp.	WO_3 Concent-rations	Thi. (cm)	662 Kev Energy		1172 Kev Energy		1332 Kev Energy	
			$\mu(cm^{-1})$	HVL(cm)	$\mu(cm^{-1})$	HVL(cm)	$\mu(cm^{-1})$	HVL(cm)
Ep (pure)	0	1	0.06991	9.9148	0.06768	10.239	0.06169	11.235
Group (1)	10%	1	0.09691	7.1517	0.07694	9.0070	0.06830	10.1485
	20%		0.10289	6.7412	0.08462	8.1895	0.07475	9.2728
	30%		0.11351	6.1051	0.09021	7.6820	0.08213	8.5849
	40%		0.12691	5.4605	0.09777	7.0880	0.09172	7.5572
Group (2)	10%	2	0.09887	7.0092	0.07936	8.7323	0.07542	9.1904
	20%		0.10534	6.5786	0.08647	8.0143	0.08279	8.3723
	30%		0.11641	5.9530	0.09560	7.2489	0.09197	7.5366
	40%		0.13098	5.2908	0.10470	6.6183	0.09994	6.9356
Group (3)	10%	3	0.11035	6.2800	0.07972	8.6929	0.07875	8.8018
	20%		0.11591	5.9787	0.08755	7.9154	0.08585	8.0739
	30%		0.12620	5.4912	0.09587	7.2285	0.09260	7.4853
	40%		0.13333	5.1987	0.10478	6.6138	0.10156	6.8250
Group (4)	10%	4	0.11234	6.1687	0.08771	7.9010	0.08472	8.1816
	20%		0.11767	5.8893	0.09236	7.5032	0.08845	7.8365
	30%		0.13021	5.3220	0.09955	6.9613	0.09350	7.4133
	40%		0.14648	4.7310	0.10574	6.5538	0.10384	6.6751

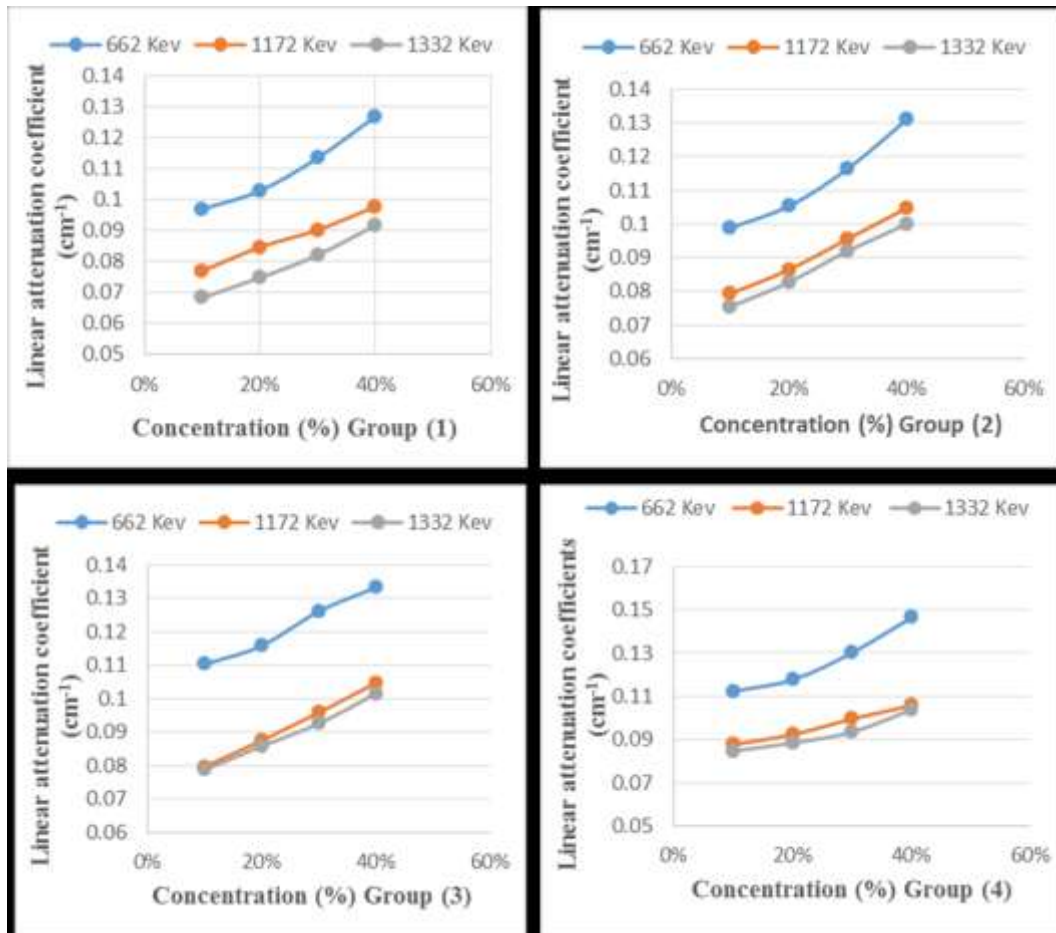


Fig.2 The relationship of the linear attenuation coefficients with the concentration of the reinforcement material for the different energies of the shields Group (1), Group (2), Group (3) and Group (4).

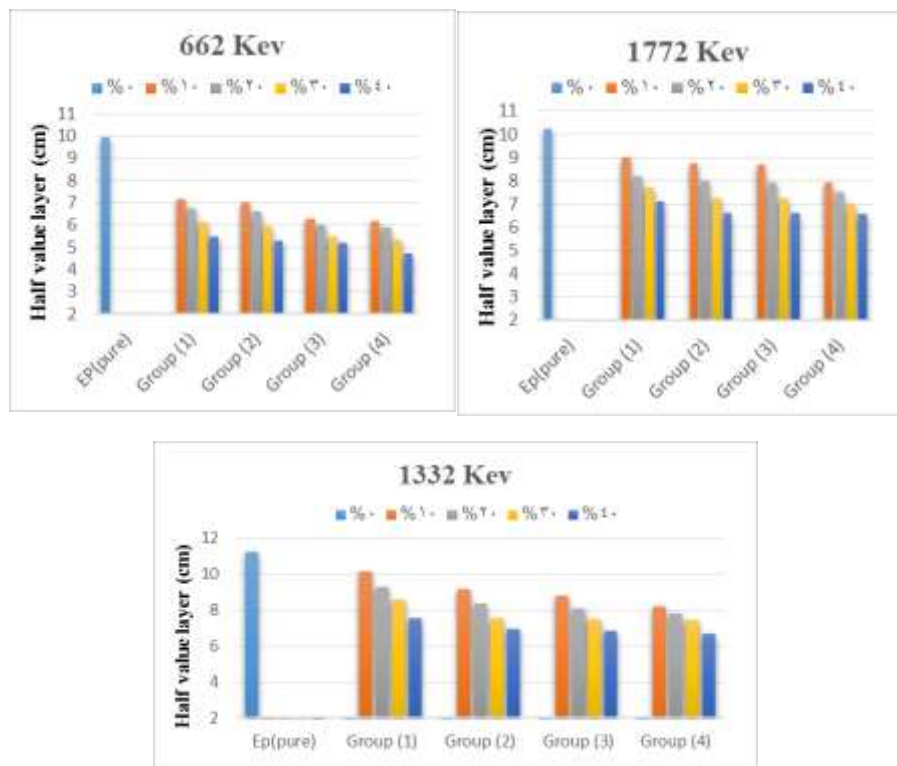


Fig. 3 Half value layers of the composites (662,1172 and 1332 Kev).

As The rate of radiation dose for gamma irradiation was calculated using Eq.3, mentioned in 2.2, The results are summarized in Table 2 For each of the (Co-60) and (Cs-137).

And Fig.4 shows the relationship between the values of radiation dose rate and gamma rays for different concentrations of (WO_3) and different thickness for radioactive sources (Co-60) and (Cs-137).

In this Fig.4 Note that the values of radiation dose rate change with change sample thickness, where we note that the values of radiation dose rate decreases significantly when increasing the thickness of the shield and specifically at the concentrations of high and both two sources, and so on because Increase energy absorption by material atoms when thickness increase, these results are consistent with studies [12,13,14].

As well as note through Figure 4 and Table 2 The dose values for the gamma ray are decreasing whenever increased concentration consolidation material nanoparticles (WO_3), and both two sources, because increased attenuation coefficient when increasing the percentage of consolidation leading to the absorption of a large proportion of photons and thus reduce the radiation intensity of the radioactive source.

Where it is when proportion low consolidation The process of dispersion of photons will be increased and less absorbed, as the proportion of consolidation increases the absorption process will increase and the probability of dispersion of the photons will decrease, we also note that the proportion of photons scattered will increase with increasing energy. this is consistent with studies [14,15].

Table (2): Comparison of gamma- ray dose rate for nanoparticles shield at different concentrations and thickness. of radioactive sources (Cs-137, Co-60).

Group No.	WO_3 Concent-rations	Thi. (cm)	Cs-137 (662 Kev)	Co-60 (1172- 1332 Kev)
			Dose-Rate ($\mu Sv/hr$)	Dose-Rate ($\mu Sv/hr$)
None	-	-	0.91	37.39
Ep (pure)	0	1	0.8485	35.0117
Group (1)	10%	1	0.8259	34.7381
	20%		0.8210	34.4950
	30%		0.8123	34.2954
	40%		0.8015	33.9750
Group (2)	10%	2	0.7467	31.9973
	20%		0.7371	31.5368
	40%		0.7209	30.9644
	50%		0.7002	30.4427
Group (3)	10%	3	0.6535	29.4461
	20%		0.6472	28.7961
	30%		0.6232	28.1569
	40%		0.6099	27.4120
Group (4)	10%	4	0.5806	26.4620
	20%		0.5683	26.0256
	30%		0.5405	25.4043
	40%		0.5065	24.5635

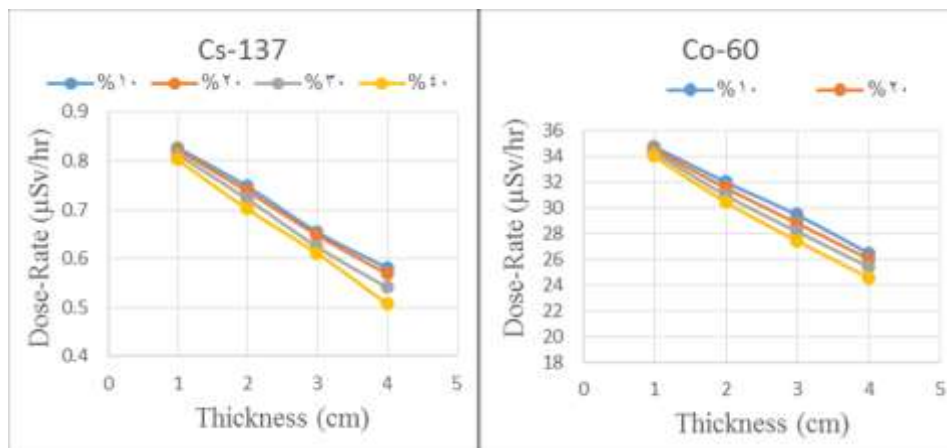


Fig4 The relationship between the dose rate and the gamma ray of the sample thickness of the source Cs-137 and Co-60 for all concentrations.

Conclusion

The selection of suitable materials for the prevention of ionizing radiation has become a major research topic. The selection of materials that are attenuated to radiation depends mostly on the type of radiation, the amount of radiation and the radiation energy. In this study, we studied the performance of nanomaterials in gamma ray attenuation.

Therefore, we can provide some important conclusions from this paper:

1-The addition of Nano-tungsten oxide to the epoxy base material in different concentrations Positive results have been obtained compared with other

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دراسة خصائص التوهين الإشعاع للدروع المكونة من الايبوكسي مع اوكسيد التنكستن للوفاية من أشعة كاما

فارس صالح عطاالله¹، كريم خلف محمد²، كمال محمود علي¹

¹قسم الفيزياء ، كلية العلوم ، جامعة تكريت ، تكريت ، العراق

²قسم الفيزياء ، كلية العلوم ، جامعة النهريين ، بغداد ، العراق

الملخص

في هذا العمل، تم دراسة خصائص التدرج لأشعة كاما للدروع المكونة من بوليمر إلابوكسي كمواد أساسية، مدعمة بأوكسيد التنكستن (WO_3) النانوي، بنسب تدعيم مختلفة (10،20،30،40%)، وإسماك مختلفة، لتحديد مدى ملاءمة هذه الدروع للاستخدام في الحماية من أشعة كاما، تم قياس بعض المعلمات مثل معامل التوهين الخطي (μ) ، السمك النصفى، باستخدام مصدر (Cs-137) باعث لأشعة كاما بطاقة (662 Kev) ، والمصدر (Co-60) الباعث لأشعة كاما بطاقات (1172،1332 Kev). لهذا الغرض، تم استخدام كاشف إيوديوم الصوديوم (NaI (TL) بحجم (1.5" × 1.5") بوصة. كما تم حساب معدل الجرعة الإشعاعية باستخدام معاملات التوهين. وأظهرت النتائج أن معامل التوهين الخطي يزداد عندما تزداد نسبة التدعيم والسمك الدرغ ويتناقص عند زيادة طاقة أشعة كاما لمصادر الإشعاع المستخدمة. أظهرت النتائج أن معدل الجرعة يتناقص مع زيادة نسبة التدعيم وسمك الدرغ، وفي المقابل يزداد بزيادة الطاقة والنشاط الإشعاعي للمصدر. أما بالنسبة لقيم السمك النصفى فتتخفض عند زيادة نسبة التدعيم، ويحدث العكس عند زيادة الطاقة.